ENVIRONMENTAL MONITORING OF CHILIKA LAKE REGION, ORISSA USING INTEGRATED REMOTE SENSING AND GIS

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by
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CERTIFICATE

Certified that the work presented in this thesis entitled **"ENVIRONMENTAL MONITORING OF CHILIKA LAKE REGION, ORISSA USING INTEGRATED REMOTE SENSING AND GIS"** by **Mr. Tapan Kumar Das** has been carried out under our supervision and has not been submitted elsewhere for any degree.

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DEDICATED TO MY PARENTS

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ABSTRACT

This study has investigated on integrated approach using Remote Sensing and GIS, for monitoring a few environmental parameters around Chilika Lake region, Orissa. The thesis aims at the qualitative and quantitative analysis of several factors influencing the natural environment of this largest brackish water lake of Asia. Main input variables to this approach are information on land use / land cover along with available ground truth information on land and water characteristics combined with the digital satellite imagery from IRS 1B LISS I sensor. Land cover has been derived from classification of remotely sensed imagery. ILWIS 1.4, a commercially available GIS has been used for integration of large amount of spatial data and to facilitate data manipulation for the various applications. Flora and forest classification have been performed on satellite imagery and compared with the classification of available ground truth data. Change in water quality parameters like temperature, pH, salinity and transparency have been quantified and compared for temporal variability. Temporal change for weed coverage area and dense forest area have also been estimated.

BACKGROUND OF THE WORK

1.1 INTRODUCTION

Chilika lake is a pretty and imposing natural water body, the largest of its kind in the country. It is a major attraction for the migratory birds from the north. Its aesthetic appeal draws large number of tourist to its shores. The margin of the lake as well as islands on its eastern fringe are dotted with settlements with fishermen dominating the population. The lake is the major occupational source for them. In recent years, problems have cropped up in exploitation of fishery resources. The lake itself is undergoing changes due to heavy fresh water discharges mainly by Daya and Bhargavi branches of Mahanadi and resultant silt deposit through out the lake. The northern fringe is heavily sedimented and large areas have emerged out of waterspread. The islands also have the rims of silt deposits around them. The windy channel connecting the sea has also been silted up. The sea inlet frequently changes its position and is quite constricted at present. Large areas of the northern part of the lake have lost its brackishness and weeds are spreading at very fast rate. In view of the above observations, a systematic study of the lake resources and environment is required. Study of natural phenomenon, occurring in the surrounding area of Chilika lake, is highly essential for proper monitoring of the eco-system. Various themes like geology, geomorphology, vegetation, wasteland, soil, agriculture, drainage, settlement have been studied by interpretation of satellite data (IRS 1B, LISS I) after selective ground truthing. Quantitative analysis of land use / land cover, type of vegetation and wasteland classes, human and other biotic inferences has been conducted to assess the impacts of these aspects over the Chilika lake environment. Remote Sensing data has been

analysed along with ground truth information. There is a serious inadequacy of information concerning the ecological dynamics of it. Although, there exists ample literature on various aspects of this system, there is hardly any analysis of its holistic nature or synoptic dynamism. The numerous field studies have not synoptically included time and space dimension, nor that the model studies have simulated all relevant processes. Therefore, even as we understand the general principles governing this environment, we are ignorant of the quantitative nature of changes on a time-space continuity. As a result, any permanent or long term development plan formulated today is to be termed premature. The immediate necessity is to create a highlevel and aunthetic database which gives a far better insight in coming years and enables a better planning for environmental development. It is now universally recognised that in the context of environment, wetlands play a very important role. These wetlands protect and improve the quality of water and keep the local climate moderate. The Chilika lake region is one of the most productive areas in our ecological system. Disappearance of such wetlands has caused changes in weather condition, reduction of subsoil water level and imbalance in the socio-economic conditions of the nearby people who depend on the resources of this wetland. Chilika is now facing a bunch of problems like siltation, extensive weed growth, depletion of fishery resources and change of its salinity. Both the state government and central government are paying serious attention to the problems of Chilika. The state government has set up a body called the Chilika Development Authority (CDA) under the Forest and Environment department who were ensure the developmental and research works of chilika. The Committee of The National Seminar on Conservation and Management of Chilika held at Bhubaneswar in 1988. Which also recommended for the establishment of Management Information System (MIS) as a long term measure in order

to acquire, store and process data. Initially a small database cell was established in the Orissa Remote Sensing Application Centre (ORSAC) in the year 1990-91. In the database information and data on Chilika lake are collected from various government departments and universities and research organisation. The present research attempts to highlights certain factors influencing the Chilika lake environment.

1.2 OBJECTIVES

Objectives of this research are as follows

a. To prepare a database of few parameters indicative of the status of the Chilika lake environment using integrated Remote Sensing and GIS techniques.

b. To assess changes in these environmental parameters over time and identify possible causes of the same.

1.3 ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

The essential steps in an Environmental Impact Assessment are

(1) Prediction of anticipient changes in an environmental descriptor.

(2) Determination of magnitude or scale of the particular change.

(3) Application of an importance or significance factor to the change.

One of the major impacts from many actions is evidenced by changes in water quality both in the vicinity and downstream from project area. Basic steps associated with prediction of changes in water environment and assessment of impact of these changes are as follows:

1. Determination of type and quantities of water pollutants emitted from all alternatives.
2. Determination of existing water quantity and quality levels for surface water courses.

3. Unique pollution problems that have occurred or are existing in local surface water courses.
4. Assembly summary of key meteorological parameters for area, noting articulately the average of precipitation, evaporation and temperature.
5. Summarise the organic waste load allocation study for the area.
6. Also procure exact information on inorganic, thermal, sediment and bacteria waste load. Identify the known point sources of pollution, focusing specifically on unique discharges or waste water constituent.

Operational impacts of alternatives are considered in terms of the following factors.

(1) Frequency distribution of decreased quality and quantity.

(2) Effects of sedimentation on the stream bottom ecosystem.

(3) Anticipated distance downstream of decreased water quality and the implications for water users and related raw water quality requirement.

(4) General effects on any water quality changes on the system ecosystem

1.4 DATA RESOURCES USED

For the present study Survey of India (SOI) toposheets, ground truth information, and remote sensing satellite data of IRS 1B LISS I are used. SOI restricted toposheets are procured from SOI, Bhubaneswar, ground truth data from different organisations involved in the research on this lake, and remote sensing satellite data from NRSA, Hyderabad. These are described below.

1.4.1 SOI toposheets

Restricted toposheets are procured from SOI, Map division, Bhubaneswar. The maps procured are shown in table 1.4

Table 1.4 Details of topographic maps procured from SOI

Scale	Edition	Year of Survey	Map no.
1:250000	First	1972-73	74 E
1:50000	First	1972-73	74 E/9
1:50000	First	1972-73	74 E/6
1:50000	First	1972-73	74 E/3
1:50000	First	1972-73	74 E/2
1:50000	First	1972-73	74 E/5
1:50000	First	1972-73	74 E/1
1:50000	First	1976-77	74 A/15

1.4.2 Ground truth information

There are 20 stations uniformly located inside the entire lake for collection of water quality parameters are shown in Figure 1.1 Water qualities parameters are recorded each day and taken as an average for a month for different analysis. The satellite data in digital form was procured for the month of July 1996, as ground truth information was available for the same. Hard copy historical data of different parameters like bathymetric m[illegible] lora map, temperature contour, salinity contour, soil map, settlement map, vegetation map,

wasteland map, temporal change of water spread area, land use/land cover, drainage map have been collected from different sources.

1.4.3 Satellite data

Satellite digital data of IRS 1B LISS I have been procured on a 250 MB catridge tape for 10th July 1996. The path and row number of this data are 20, 54 respectively. A full image scene has been procured.

1.5 OVERVIEW OF THE METHODOLOGY

The present research has been conducted for preparation of a database for Chilika lake and its surrounding area. After procurement of ground truth data and maps, the portion under consideration is extracted from the SOI toposheet no. 74 E. The area is digitised after transformation of co-ordinates from *geographical* to *lambert conformal conic.* Other maps are digitised with respect to their maximum, minimum latitude and longitude. All the digitised maps are georeferenced with respect to land use /land cover map (largest map). The point information are also digitised. The required digitised maps polygonized and rasterized. Satellite digital data is georeferenced with respect to land use / land cover map. Maximumlikelihood classifier is used for land cover, flora and vegetation classifications. Area covered by each component is also calculated from historical ground truth data and compared with the classified satellite image. Difference in water quality parameters are also traced out by density slicing of two different interpolated maps of different years. The change in waterspread area from 1914 to 1996 is also estimated. For the analysis the common analysis the commonly available GIS package ILWIS 1.4 (Integrated Land and Water Information System) and ALTEK digitizer has been used.

DETAILS OF CHILIKA LAKE

2.1 DESCRIPTION OF THE STUDY SITE

Chilika lake, a unique ecosystem of the globe is the largest Asian brackish water lake. It is situated between latitude 19^0 28' to 19^0 54' N, longitude 85^0 05' to 85^0 38' E, covering part of Puri, Ganjam and Khurdha districtsof Orissa. It is connected to the eastern site of Bay of Bengal through a narrow channel (about 1.4 km wide) of about 25 km. It is separated from the Bay of Bengal by a barrier spit of about 61 km. (Katre & Das) The base map is as shown in the Figure 2.1. The inlet near the bay is constantly shifting towards north due to littoral drift and is gradually narrowing down with time. At present the width is about 180 m. In 1992 it was 195 m. Nuna, Kusumi, Salia, Daya and Bhargavi are the main tributaries along with other perennial streams, which discharge about 3 lakh cusec fresh water into the lake. These are the main sources carrying 3·65 lakh tonnes of silt annually to the lake jeopardising the existence of the lake. During high tides, salt water gets into the lake through the narrow channel from the sea. Due to exchange of water between the lake and the sea, the lake has brackish water character.

2.2 PHYSICAL ASPECTS, AREA, LEGAL STATUS

a. Physical aspects

The physio-chemical characteristics of the lake are typically lagoonal.

b. Area

The lake water spread area is about 900 km^2 in summer. Average water spread area increases upto about 1050 km^2 during monsoon.

c. Legal status

Chilika wild life sanctuary comprises of 15.53 km^2 of area and the rest of the area of the lake has been declared as "closed area" under the provision of Wildlife Protection Act 1972.

2.3 FEATURES AND PROCESSES IN CHILIKA LAGOON

2.3.1 Features

Table 2.1 Features of Chilika lake

Features	rainfall	1450 mm (June-September. monsoon months): seen to increase from SW-NE and varies from 1200-1600 mm
	temperature	26.6^0C to 27.7^0c maximum: 36.0^0 c (Mar-April) minimum: 16.0^0 c (Dec.-Jan)
	wind-speed	varies from 10 km.p.h. (winter) to 25 km.p.h. (summer); coastal areas experience more forceful winds.
	vegetation	Moderate undergrowth & grassy land.
	radiation	Mean incident solar radiation varies from 90 cal/cm^2 per day (February-March) to 150 cal/cm^2
	sunshine	mean daily duration of sun shine varies from 9 hours (winter) to 4-5 hours (monsoon months)

2.3.2 Morphology and development

Table 2.2 Morphology and development of Chilika lake

Morphology and Development	Lagoon	Shallow linear elongate arms, coast parallel; Total no of rivers : 10 Depth shows a wide variation in different parts a. Northern part shallow 0.5 to 1 meter b. Deeper part on southern side of Rambha from 2 m depth average c. Deepest near Kalijai island 2.75 to 3 m. d. Channel area varies from 0.01 to 0.02 m depending upon tidal inflow.
	Barrier	Wide sandy islands with multiple beach ridges seaward progradation and long-shore migration
	Mainland margins	Swamps, marshes & tidal flat locally
	Inlet	Narrow few ephemeral barrier breaches

2.3.3 Water characteristics

Table 2.3 Water characteristics of Chilika lake

Water	character	Salinity : 10.2-11.2 ppt in northern area; 17.8-28.0 ppt in middle area due to influx of seawater 16.0-16.8 ppt in southern area Partly stratified & well mixed Turbidity : 0.08-1.61 m colour : muddy yellow to green
	lagoon-sea xchange	Moderate tidal exchange, high during river floods Dissolved O_2 : 6.7-7.5 mg/L; Total Alkalinity: 25.8 - 157 ppm; Phosphate: traces to 0.8 ppm Nitrates : traces to 0.19 ppm Silicates : 0.10 to 6.00 ppm Average plankton : 0.15 cc/l

2.3.4 Sediment sources

Table 2.4 Sediment sources of Chilika lake

Sediment Sources	Primary	Rivers and streams Volumes of annual fresh water discharge : 3,75,000 cusecs
	Secondary	Barrier and shore face via inlets and wash over silt carried into lagoon annually : 3.65 Lakh annually MT.

2.3.5.Transport processes

Table 2.5 Transport processess of Chilika lake

Transport Processes	River discharge	River inflow & flooding
	Tide	Low range : 0.3 - 1.0 m Moderate tides reach upto 5-6 m & areas upto 20 km^2 inland affected by the saline water inundation
	Wave energy	Very severe storms generated by cyclonic activity (May to November) accompanied by gales, high winds and tidal waves having a destructive effect the land use pattern of chilika lake area & responsible for gradual shifting
	Unique Process	of the lagoonal lake mouth towards NE & for subsequent reduction of the mouth width due to settling & accumulation of the transported sands from the sea
	Seasonality	Rainwash on barrier & breaching, Lagoon flooding, flushing through inlets

2.3.6 Depositional processes

Table 2.6 Depositional processess of Chilika lake

Depositional Process	Settling of river-borne suspended load entrapment by algae & plant material flocculation & accretion at river deltas

2.3.7 Bed sediments

Table.2.7 Bed sediments of Chilika lake

Bed sediments	Central lagoon : Organic rich silt & clay or sand mud Marginal Zones : Shelly sands

2.4 PROBLEMS OF CHILIKA LAKE

Siltation

About 3.65 lakh metric tonnes of silt are deposited in the lake annually due to indiscriminate deforestation in catchment area of the lake.

Shrinkage of area

The lagoon is shrinking about km^2 per year due to siltation and encroachment in the peripheral fringe.

Choking of the Chilika inlet and outlet channel

Due to this problem the sea water is not properly circulated throughout the lake resulting in decrease in salinity and consequently water quality.

Pollution of the lake

Toxicity of heavy metals like copper, lead, zinc, nickel and others.

Weed infestation

Due to low salinity water hyacinth and other weed appear in the lake showing rapid decline of salinity.

Decrease in fish procurement

The catch of fish has been substantially reduced by 40% over last decades, due to change in ecosystem and combined operations in the lake. This adversely affects the sustenance of birds living on fishes.

REMOTE SENSING AND GIS

3.1 RELATIONSHIP BETWEEN REMOTE SENSING AND GIS

Remote Sensing provides access to spatial information on a global scale. Furthermore, new detectors and imaging technology are increasing the capability of remote sensing to acquire digital spatial information at very fine scales. The management of such information is going to be one of the major challenges of the coming decades. With advancement of space technology storage and management of data volumes has became increasingly difficult. This can be alleviated by using GIS technology. GIS is a powerful set of tools for capturing, storing, transferring, analysing, retrieving at will and display spatial data from real world for a particular set of purpose. GIS is decision supporting system involving the integration of spatially referenced data in a problem solving environment. GIS system have became a accepted as a standard way of handling geocoded data sets and performing analysis on those data for a multitude of applications. Geographical data describe objects from the real world in terms of their position with respect to known co-ordinate system, their attribute that are unrelated to position (such as colour, cost, pH, incidence of disease, etc.) and their spatial interrelation between each other (topological relations) which describe how they are linked together and how one can travel between them. Processing and information flow during integrated analysis of GIS and remote sensing data is shown in Figure 3.1. Processes are encloses in ellipse and products are in boxes.

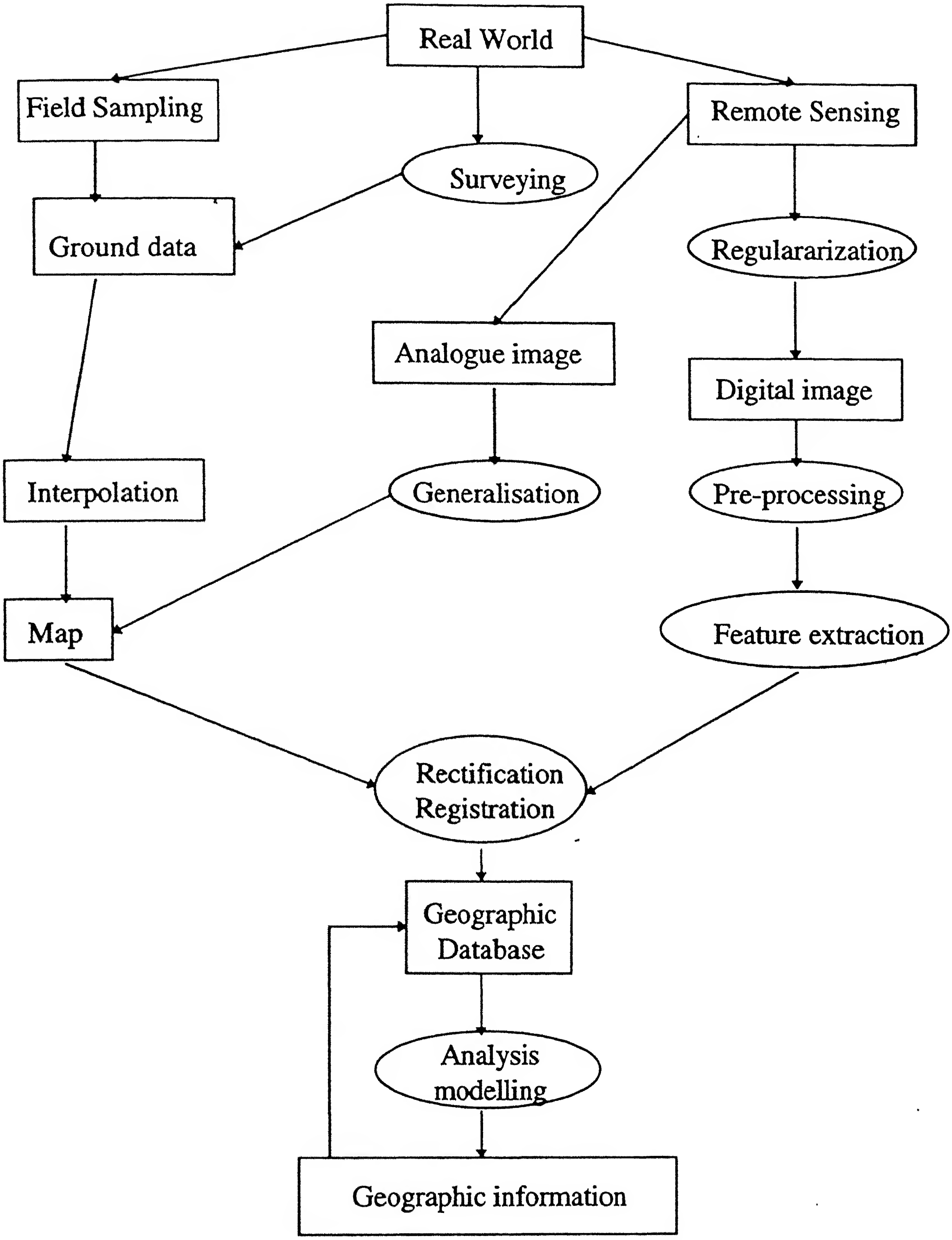

Figure 3.1 Conceptual diagram of data processing and information flow during integrated analysis of GIS and remote sensing data. Processes are enclosed in *ellipse* and *products* in boxes.

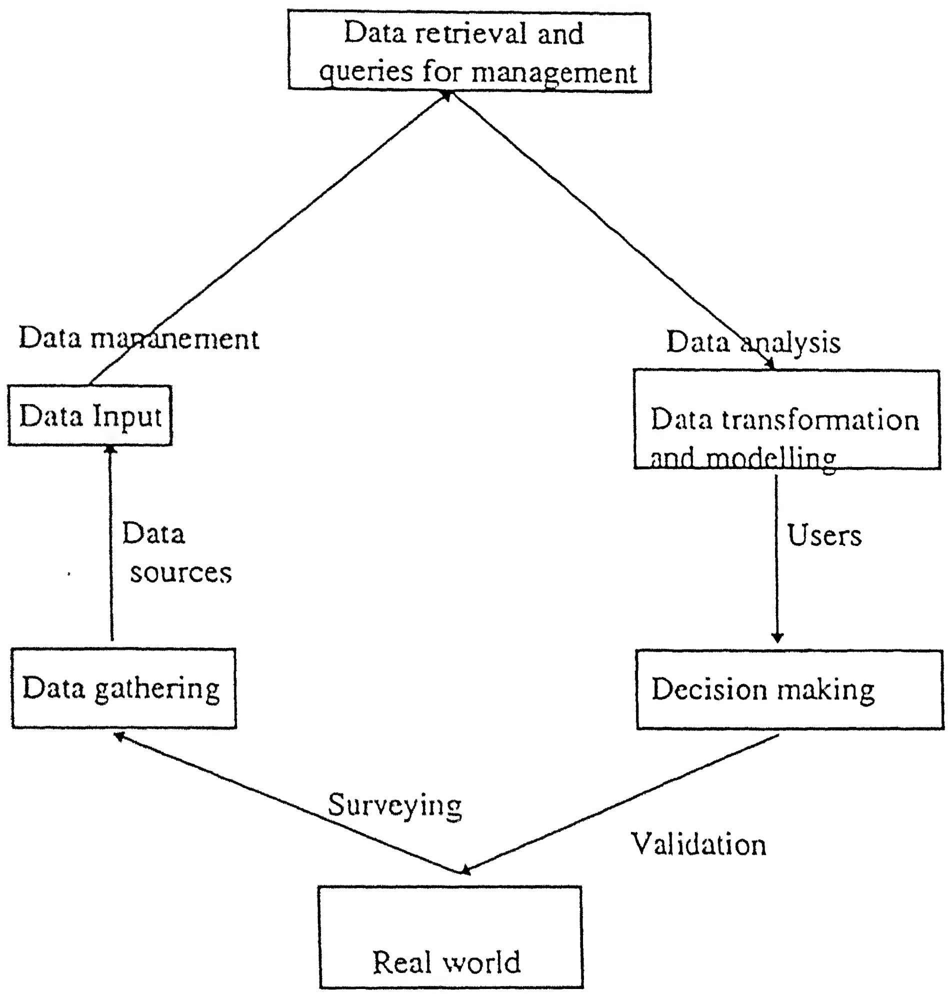

Figure 3.2 GIS as a management tool

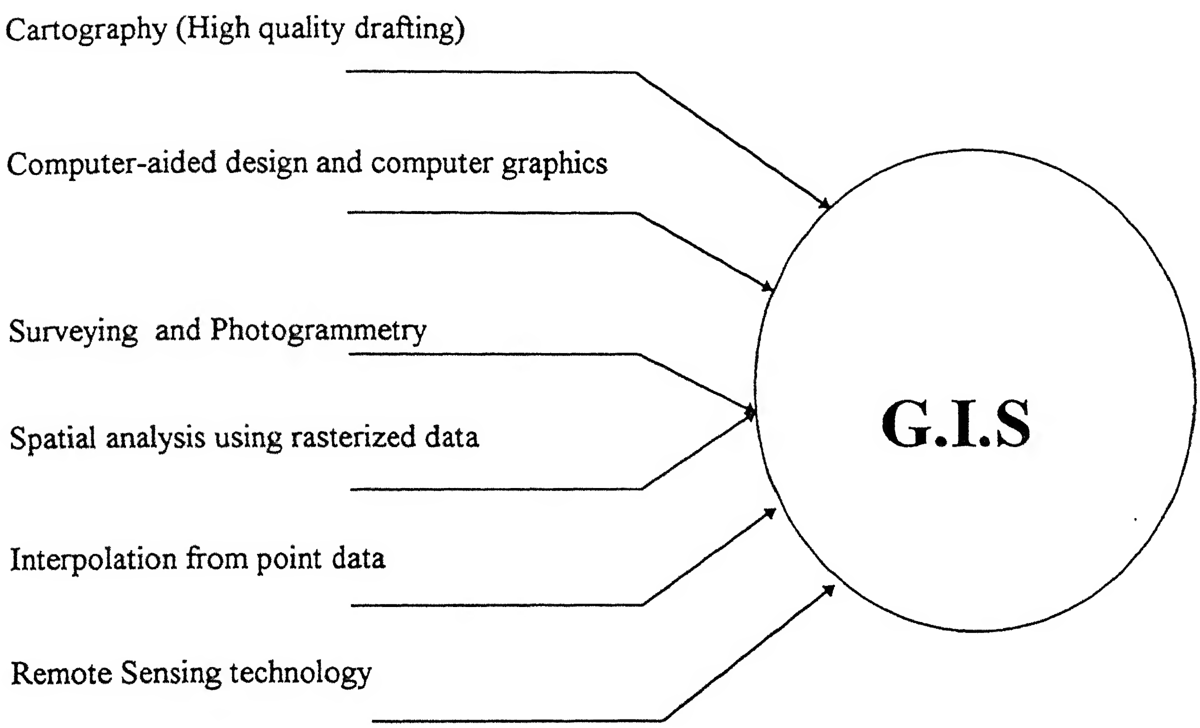

Figure 3.3 Geographical information systems are the result of linking parallel developments in many separate spatial data prosessing disciplines

3.3 RANGE OF ANALYSIS

The most important characteristics of GIS is the provision of the capabilities for spatial analysis functions. These function uses the spatial and non-spatial attributes in the database to answer questions about the real world. The objective of data analysis is to extract or query useful information to satisfy the requirements and objective of decision makers at all levels of details. An important use of analysis is the possibility of predicting what will happen in another location or at another point in time. This ability provides the possibility to select the best possible alternatives. The range of analysis procedures have been subdivided into four categories like

a. Retrieval / reclassification / measurement

b. Overlay

c. Distance and connectivity

d. Neighbourhoodness

3.3.1 Retrieval, reclassification, measurement

In these functions spatial analysis and attribute data are retrieved, but only the attribute data are modified. No changes are made to the location of spatial elements and no new spatial elements are created.

Retrieval operations on the spatial and attribute data involve the selective search and manipulation and output of data without the need to modify the geographic location of features or to create new spatial entities.

Reclassifying procedures involve operations that reassign thematic values to the categories of an existing map as a function of initial value, the position, size and shape of the spatial configuration associated with each category. For instance a soil map reclassified into a permeability map or a terrain mapping unit (TMU).The process involves looking at the attribute for a single data layer and assigning an additional attribute, the new class name. Reclassification can also be performed in multiple data layers as a part of an overlay operation. For example, a desirable area for recreational purposes might be an undulating forested area with well-drained soils and non agricultural zone. Each of these factors may be presented in different layers. An overlay analysis could be used to identify the area satisfying these criteria and then reclassify them as good recreational areas. Measurement of spatial data involves the calculation of distances between points, length of lines, area and perimeter of polygon and volumes.

Measurements involving points include distances from point to a point, a line or a polygon., enumeration of the total number of points falling within the polygon.

3.3.2 Overlay operation

Overlaying of map results in creation of a new map where the values assigned to every location on that map are computed as a function of independent values associated with that location on two or more existing maps. Overlying operation creates a new data set containing new polygons formed from the intersection of the boundaries of the two or more sets of separate polygon layers. In addition of creating new polygons based on the overlay of multiple layers. These polygons have multiple attributes, i.e. the attributes which were given to each separate overlay before the composition occurred. Arithmetical and logical overlay operations are common in all GIS software packages. Arithmetic

overlay includes operation such as addition, subtraction, division and multiplication of each value in a data layer by the value in the corresponding locations in the second data layer. Logical overlay involves the selection of the area where a set of condition are satisfied. If landuse, landforms and soil are stored in separate layers in the database, then a logical overlay operation may be used to identify the areas where these conditions are satisfied.

3.3.3 Neighbourhood operations

Neighbourhood operations involve the creation of new data based on the consideration of "roving window" of neighbouring points about the selected target locations. They evaluate characteristics of an area surrounding a specified target location. In all neighbourhood operations it is necessary to indicate one or more target locations, the neighbourhood considered around each target and the type of function to be executed on the attribute within the neighbourhood. A few typical neighbourhood operations in most GIS are search functions, topographic functions and interpolation.

3.3.4 Distance and connectivity function

Connectivity operations are those that estimate values by accumulating them over the area that is being traversed. The accumulated values can be qualitative or quantitative. In order to calculate a connectivity function, it is required to specify the manner in which the spatial elements are interconnected, the rules (possibility, constraints) that control the movement allowed along the spatial elements and a unit of measurements. Connectivity functions are grouped into contiguity, proximity, network and spread operations.

3.4 ILWIS

3.4.1 Introduction

ILWIS is an integrated Geoinformatics and remote sensing system, which provides the key to an international wealth of information for various applications including urban analysis, land evaluation, environmental management, hazard monitoring, rural development and watershed management. It is a GIS that integrates image processing and spatial analysis capabilities, tabular databases and conventional characteristics. Data acquisition from aerospace images, an integral part of the system, enabling effective monitoring. This feature is important in regions in which data are scarce or difficult to gather. The design of system takes into account that not all GIS users have a through knowledge of computers. All operations are therefore, performed through a user-friendly menu, which allows the user to concentrate on application rather than learning the intricacies of the system. Experienced user can, on the otherhand, perform operations directly through commands and/or command files.

3.4.2 Major procedures

3.4.2.1 *Data input*

A conversion programme allows import and export of remotely sensed data, tabular data, raster maps and vector files from or to other several formats. Analogue data can be transformed into the vector format by means of user friendly *digitise* programme of which the "on screen digitising" (digitising with any raster map or image as on screen underlay) is one of the most important features.

3.4.2.2 *Spatial modelling*

Complex modelling procedures can easily be executed by the "map calculator". The map calculator includes an easy-to-use modelling language and enables the use of mathematical functions and macros. It indicates the spatial and tabular databases. Complex procedures can be executed rapidly on the portions of the study area into vedeo memory. After evaluation and assessment of results, the procedure can be applied to the entire area. Tabular and spatial databases can be used both independently and on an integrated basis. Calculations and queries and simple statistical analysis can be done by the table calculator. Computational procedures and efficient use of the system are improved by the appropriate use of modelling processes. Not all analysis involves the use of spatial databases, whenever possible, knowledge driven queries in the tabular database should take precedence over similar operations in the spatial databases. Fast overlay procedures constitute one of the major characteristics of the system.

3.4.2.3 *Image processing*

Image processing capabilities integrated with spatial modelling and tabular databases constitute a powerful tool. Together they enable analysis of data which only recently been possible. ILWIS also incorporates conventional image processing capabilities such as filtering, geometric corrections and classification procedures.

3.4.2.3.1 *Special features*

For the interpolation of point data and contour lines, special programmes are available to create DEMs (Digital Elevation Models). Special filters and functions are available to produce slope and aspect maps. Functions and filters can also be defined by the user.

3.4.2.4 *Data output*

The system supports black and white and colour hardcopy output devices in either vector or raster format. It supports standard penplotters, black & white and colour matrix printers and laser printers. Conversion routines from ILWIS data formats to number of other data formats (raster, vector and tabular) are provided.

CHAPTER 4

MODULES OF ILWIS USED FOR PRESENT STUDY

Most of the modules present in this package are used for present study. However, the important modules are described below.

4.1 INPUT MODULE

The input modules enables the user to gather geographical information (vector or raster format) and attribute data. This module also enables the user to convert files with other formats to files in ILWIS format.

4.1.1 Edit MPI

Changes the Georeference, co-ordinates, transformation (scale, rotation, translation) and format (bit, byte, integer) of ILWIS raster maps as stored in MPI files.

4.2 VECTOR MODULE

In the vector module the user can digitise, display, update and rasterise vector (segment and polygon) and point data, raster to vector conversion and stream ordering analysis facilities are provided. Autocorrelation of point files can be determined. Vector module contains the sub-module *Vector to Raster* (Rasterization).

4.2.1 Digitisation

Digitise is used to transform data from analogue (paper) maps into a digital (computer compatible) format. In simple terms, digitising can be regarded as the process of recording X and Y co-ordinates values to describe the location of points, lines and areas as there are depicted in one or more maps. Nearly all current operation of scientific and operational

spatial data handling systems must deal with the complex analogue to digital conversion process by which map sheets are changed into clean, useable digital files. This transformation is accomplished by means of either manual or automatic digitisation. The latter has been shown to be economical only for very large data volumes and practical only when the map documents being scanned have been prepared according to a strict set of specifications For many operational activities, both governmental and private, and for nearly all scientific applications. The data input requires the capability of editing operations to verify the digital data against the original map and subsequently to correct the errors induced by both the user and the hardware & software. Manual digitisation represents the primary method for entering map data into the geographic information system (Peuquet and Boyle, 1984). While considerable work has been done with newer technologies, the overwhelming majority of cartographic data entry is now done by manual digitisation.

Some of the advantages of manual digitisation are described below.

1. Low capital cost, low cost labour, great flexibility and adaptability
2. With modern database error checking software's, the quality of information is high
3. The technique is simple, however time consuming
4. Error on basic map can easily discovered and updated while in the process of entering the information
5. Digitising devices are very reliable
6. Scanning may not may not provide the required data precision
7. Maps of poor quality and condition may cause error by scanner

The following list describes the main characteristics of the digitised programme :

1. Input of the line and point elements
2. Digitising of paper map, raster image backdrop (on screen digitisation) or both
3. Automatic input checking
4. Point, line and polygon encoding
5. Windowing and zooming
6. Editing options: adding new elements, deleting elements, undeleting elements, code manipulation, automatic editing
7. Data reduction (tunnelling) and compression
8. Storing of spatial data in vector format on hard disk or floppy disk
9. Topology building
10. Creation of polygons and polygon management

The ILWIS package supports manual digitising using an electromagnetic, electrostatic device called a digitizer. The digitizer converts the movements of a cursor or point locator into electrical identified locations which are read directly into the computer. The digitised programme has its own menu structure. The menus appear on the screen in blocks of 4 commands. Commands can be selected by pressing one of the first four buttons of digitizer mouse. The numbers preceding the commands indicate the cursor button that should be pressed to select this option. The actual character that appears in digitising programme can be chosen in the configuration programme. If a command is selected a new block appears on the screen. If no command option in the menu is indicated behind one of the cursor buttons, the button has function in this block. At certain points in the programme the user is asked to enter commands using the key board in order to:

a. to conform an action to be undertaken by the programme

b. specify file names

c. specify names, code and/or colours of points, lines and polygons

d. specify control points

The programme is divided into three parts or modes: the *segment mode*, for digitising and managing segments, the *point mode*, for digitising and displaying points and the *polygon mode*, for polygonizing vector maps and managing polygon files. The stepwise operational procedure and the key features of the digitisation programme are as follows:

4.2.1.1 *Co-ordinate transformation*

A link between the map and the digitizer co-ordinates has to be made to be able to digitise and manipulate map data using the co-ordinate system of the map. This can be done by specifying control points. When a control point is digitised, the corresponding real world (metric) co-ordinates is entered in order for the programme to be able to calculate a transformation between digitizer and real world co-ordinates. Control points need to points for which the co-ordinates can be determined accurately, they can well be grid line intersection or triangulation points. In the present study, the corner points of the multiple maps used were selected as the control points. The metric co-ordinates of these points were previously determined by transformation from the geographical to Lambert Conformal Conic projection. A minimum of three points has to be digitised and an affine transformation involving the rotation and scaling of the co-ordinate axes is carried out. The transformation coefficients are displayed on the screen in order to check the result of the transformation and to ascertain whether the control points have been correctly

inserted. The value of sigma (in digitizer units) calculated along with the transformation coefficients gives the measure of the accuracy with which the control points have been digitised. If the accuracy is not acceptable, provisions exist for deletion or addition of existing and new control points respectively. For the present study the value of sigma was restricted between ± 3 throughout.

4.2.1.2 *Digitisation modes*

After a satisfactory co-ordinate transformation, the programme is ready to accept positional information within a user-defined window and on the transformed co-ordinate system. As mentioned earlier, three modes of digitisation are available with ILWIS, viz.; the *point mode*, the *segment mode*, and the *polygon mode*.

4.2.1.2.1 *Point mode*

The operations in the point mode are similar to those in the segment mode except for the fact that points are not identified by codes as applicable to segments, but by an alphanumeric code (upto 15 characters). The alphanumeric point identification is displayed on the screen, and the position of the digitised point is indicated by a + symbol. The points digitised can be stored for future reference in a point file which are created on command and new points can be added and erroneous points can be deleted from the screen as well as the file.

4.2.1.2.2 *Segment mode*

A line can be digitised in two ways: Curved segments are digitised by pressing the button of the cursor continuously. In this way the co-ordinates are recorded continuously. This

way of digitising is called the *stream mode* of segment digitisation. Straight lines are digitised by pressing the button of the cursor non continuously. In this way the co-ordinates are only recorded when and where the button is pressed. In practice this means that the button is pressed only at the begin and end points of a line. This way of digitising is called point mode.

4.2.1.2.3 *Polygon mode*

There is no direct option for digitising polygons. First the polygon map is digitised as a segment map. Then user has to go in following steps

1. Check / make / update
2. Make / update

During this operation the computer checks each segments and dead ends. After elimination of all errors it starts creating polygon files. This is the most time expensive operation in this system. If an error is detected the process of segment checking starts from the beginning after the due correction of the error. For polygonization of landuse / land cover map around 500. hours have been spent.

4.2.1.3 *Code and mask*

Two other important feature of segment mode digitisation are codes and mask. Digitised segments can be assigned an attribute *code*. For instance, a segment representing a road could have a code *road* to differentiate it from a segment representing a river, having a code *river*. When an isoline map is digitised, the segments have the numerical value of the

isoline as the code. The code should be specified preferably before digitising the segment. All segments digitised are assigned the current code automatically. It is possible to change the code of a given segment later. A segment can only have one code. If no code has been specified, all segments will have a default code (B00). Another concept that is associated with GIS activities is the storage of data in *layers*. It is not always necessary to display all segments at the same time. It may be useful to display only the segments with a specific code(s). In a *mask*, the codes of the segments which should be displayed can be specified. Multiple codes can be specified in one mask. The current code should always be specified in the mask, to be able to see the currently digitised segments.

4.2.1 Segment Densities

Segment densities calculates segment densities (in meters per square meter) and number of segments per polygon or (user defined) grid cells for segment or polygon maps. The programme asks for the name of the vector map for which the densities should be calculated. If for the specified map name a network file exists, the programme proceeds automatically to the *'Network File Logger'* instruction screen. Network file can be created in network if no network file exists the programme proceeds with the questions '*Multicolour* ?(y,n) n :

If confined: The segments are displayed in multicolour, i.e. each different code in different colour. Proceeds to the *'segment code & colour'* instruction screen.

If rejected: The segments are displayed in one uniform colour. Proceeds to the *'segment code & colour'* instruction screen.

4.2.3 Display and Change

Display and change is provided with the function to display and manipulate vector data : segment maps, polygon maps and point files. The following facilities are included :

1. Display of segments, polygons and points on the colour screen
2. Overlay of vector maps on the raster maps displayed on the colour screen
3. Code retrieval of segments and polygons
4. Renaming, masking and recoloring facilities
5. Co-ordinate transformation of a vector map
6. Automatic polygonization and levelling facilities
7. Lineament analysis (length of the segment in each direction)
8. Node point extraction

The programme asks to display one of the following options :

1. Segments
2. Polygons
3. Points

Then it asks for the part of the screen on which user wants to display i.e. window. Afte selection of the window, again user has to choose the mask with which the prementione option will be displayed. Else the default '*' (includes all codes) is taken into account.

4.2.4 Change Projection

Change projection transforms vector maps (segment maps with .CRD, .SEG and .SLG individual co-ordinates pairs and point tables from their current cartographic projection t another projection. Polygons defined for source map (stored in .POL, .TOP and .PLI file:

can still be used for the transformed (target) map. The manual option of this module is being used for the present study. It allows the transformation of points from one projection (the source projection) to another (the target projection). This option is specially useful for georeferencing paper maps in the digitise programme using control tie points, when on these maps only geographic co-ordinates are indicated. These points can be transformed to their metric equivalents. It is to be noted that ILWIS digitise program only accepts metric co-ordinates as input. Based on criteria related to the shape, size and location of the area on the globe to be projected, the available projections can be divided in cylindrical, conical, azimuthal and other projections. Projections can also be grouped according to the type of distortions they produce on a map or more specifically which properties of the globe are retained in the projection. In the present work the source projection is *Geographic* and target projection is *Lambert Conformal Conic.*

Geographic

Geographic co-ordinates in degrees, minutes, seconds (for option manual), or in seconds (for option tables and segments)

seconds = 3600 * degrees + 60 * minutes

Ellipsoid supported for India is *Everest ellipsoid*

Everest ellipsoid of 1830

Equatorial radius = 6377276.3m

Polar radius = 6356075.4m

Projection parameters:

1. central meridian

2. longitude of origin
3. latitude of origin
4. false easting: shift towards the east indicating the differences between the origin of the projection and a redefined origin. A reason to redefine the origin might be to obtain positive co-ordinates on the map.
5. false northing: shift towards the north indicating the difference between the projection origin and redefined origin
6. first and second parallels

Central meridian is taken the mean longitudes of the map to be digitised. We have ground truth data related to different parameters of different scale and location. First each map is digitised taking first parallel as minimum latitude, second parallel as maximum latitude, central meridian as approximately mean of the minimum and maximum longitude, false easting as 0 (zero) and false northing as 0 (zero) of that particular map. Then with reference to the land use and land cover map (the biggest map of Chilika region), each map is georeferenced.

4.2.5 Rasterize

The vector to raster module converts vector maps to raster maps and creates corresponding attribute data files. *Segments to raster* converts vector maps consisting of segments to raster maps and *Polygon to Raster* converts vector maps consisting of polygons to raster maps. Rasterization from points creates a raster map out of a point table (.pnt). The table should have the columns X!, Y! and optionally one or more attribute columns. Pixels in the raster map that represent points can have as value an

attribute value (defined in the attribute column), a record number (defined in the point table) or be one. Pixels in the raster map that donot represent a point will have a value zero.

Polygon to raster converts polygon map into raster maps. The pixel size and portion of the map to be rasterized are user defined. Also the transformation from an existing raster map can be copied. Either separate polygons or mapping units (groups of polygons having the same name) can be taken as unit, i.e. polygon names can be converted to pixel values. Pixel values filling different polygons or mapping units in the raster map can be attribute values taken from an attribute table. The programme generates a map data file (.mpd) a map extention file, a map information file (.mpi) and an information table (.inf). The latter can be used to link attribute data to the raster map in *Mcalc* and *TabCalc*.

Segments to raster converts segment maps to raster maps. The pixel size and portion of the map is to be rasterized are user defined. Also the transformation from an existing raster maps can be copied. An option to assign attribute values to the segments is included. This implies that segment codes can be converted to numbers (i.e. pixel values) in the resulting raster map. The programme generates a map data file (.mpd), a map information table

(.mpi) and under certain circumstances, an information table (.inf)

4.3 RASTER MODULE

The raster analysis module enables the user to process, analyse and visualise the geographical information stored in the raster format (digitised and rasterized maps and remotely sensed images). The raster module also enables the user to georeference raster

maps and link raster maps with the attribute data stored in the internal ILWIS database. The raster modules consists of the sub modules *Visualisation, Spatial modelling and Image processing*.

4.3.1 Visualisation

The visualisation module enables the visualisation and storage of raster maps. It contains the sub-module *WINDOW*.

This module is having following options of operations

1. *Display & Store:* displaces or stores raster maps on /from the colours screen
2. *Colour Lut:* selects, manipulates, updates & creates colour lookup tables
3. *Pixel Info:* retrieves information about individual pixels for one or more raster maps and polygon maps and table linked to this maps. Automatic zooming is performed. Edits pixel values on the colour screens or pixel values of maps on disk.
4. *View Values:* Display pixel values of raster maps line by line in ASCII on the monochrome screen or sends them to a printer.
5. *Display 3D:* Display grids or raster maps in 3D perspective on the colour screen and enables the editing of the view parameters defining the perspective.
6. *Stereo Pairs:* Creates stereopairs.

4.3.2 Spatial modelling

The spatial modelling modules enables interactive modelling and analysis using one or more raster maps and/or tables. It contains the sub-modules *Interpolation, Georeferencing and Map Calculation.*

Interpolation module enable interpolation between points and isolines. From isolines it performs linear interpolation. From raster it interpolates between individual raster elements on grid basis. It is provided with bi-linear and cubic-spline interpolation facilities. From points it interpolates between two predefined points. It is provided with nearest neighbour, moving average, trend surface and moving surface interpolation algorithms. User defined limiting distance and weight functions for all algorithms are also included.

Georeferencing module enables the user to georeference a raster map or to perform geometric transformation of raster maps. *Geometric Transformation* sub module of this is considered for the present study. It resamples a raster map to a georeferenced co-ordinate system by specifying tie points manually. It resamples a raster map to another map.

Map calculation performs spatial analysis on multiple input raster maps for map overlay and various other spatial analysis functions incorporates logical, arithmetical, conditional and neighbourhood operators, including iterations. Integrates attribute information.

4.3.3 Image Processing

The image processing module contains all the standard image processing facilities and some extra statistical features. It can be used to process remotely sensed data and data derived from other sources can also be processed digitally. This module contains the sub module *Statistics* and *Classification*. It has option for *stretching* (linear stretch and histogram equalisation), *Colour Composite* for creating FCC using 3 bands of image with fixed and dynamic colour look up table. It also provides the filter module for spatial enhancement and analysis of raster maps.

Statistics performs different types of statistical analysis like calculation and display of histogram, PCA, autocorrelation and semivariance of a raster map.

Classify performs multispectral classification using class statistics (sample set) obtained in the sample programme (smpl) on a maximum of 4 bands or using statistics obtained in the cluster programme (cluster) on maximum of 8 bands. The bands used in sample classification correspond to the bands used in classification. *Classification* module incorporates a sampling facility and different types of classification algorithms to be used for supervised classification. It has four sub modules like *sample, cluster, classify, density slices*. *Sample* interactively samples pixel values from a data set and statistically analyses the sample set. *Cluster* performs cluster analysis on sample sets for unsupervised classification. *Classify* incorporates box classifier, maximum likelihood classifier and nearest neighbour classifier algorithms. *Density slices* performs one dimensional classification on a raster map by defining intervals of pixel values interactively. In this research *maximum likelihood classifier* is used for classification purpose.

4.4 OUTPUT MODULE

Output enables to produce paper copies of raster and vector maps and *Annotation* (symbols, text, legend, labels) with graphics printer, or of vector maps and annotation with a plotter. Raster and vector maps and annotation can be combined into one raster map. Paper copies can be created in black and white, colour, or with user defined pattern.

Annotation creates, edits, and saves annotation files. Symbol, text or legend (title, legend, boxes, scalebar) files can be created. For all annotation size, colour and / or rotation can

be specified. Annotation can be directed to the colour monitor for display with vector or raster map, or to printer / plotter.

CHAPTER 5

METHODOLOGY USED

Restricted toposheets were procured from SOI, map division, Bhubaneswar. Historical data like temperature contour, salinity contour, transparency contour, water spread area from 1914-1992 etc., were collected from published papers of different journals and different government organisations. IRS 1B digital data was procured for the month of July 1997 as ground truth information like physical, chemical and biological characteristics of water collected from 20 different stations located uniformly through out the lake was available for the same. The area under consideration is extracted from SOI toposheet number 74E on 1: 250000 scale and digitised after transformation of geographical to metric co-ordinate (digitizer co-ordinate system) through the use of sub module *Change Projection* of *Vector module.*

The ground control points taken for the basemap extracted from SOI toposheet are four extreme points (corners). We can take any point on the map as ground control point if and only if after transformation the sigma value is within ± 3.

The transformation process is as follows

* Vector
* Change Projection
    * Manual
    * Source Projection (Geographic)
        * Target Projection (Lambert Conformal Conic)

* Ellipsoid (Everest) Everest ellipsoid of 1830

We have the base map as shown in Figure 5.1

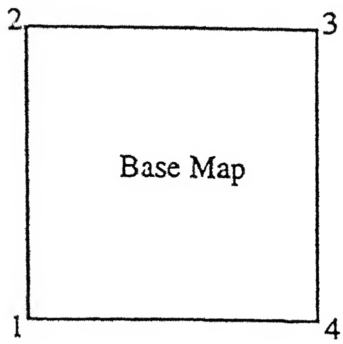

Fig. 5.1

Table 5.1 Co-ordinates of basemap

Point	Latitude (N)	Longitude (E)
1	19^0 15' 00''	85^0 00' 00''
2	20^0 00' 00''	85^0 00' 00''
3	20^0 00' 00''	86^0 00' 00''
4	19^0 15' 00''	86^0 00' 00''

The parameter used for basemap is as follows.

1. First standard parallel : 19^0 15' 00'' (N)
2. Second standard parallel : 20^0 00' 00'' (N)
3. Central meridian : 85^0 30' 00'' (E)
4. Latitude of origin : 19^0 15' 00'' (N)
5. False easting : 0
6. False northing : 0

Now programme asks for the co-ordinates of the points (1, 2, 3, 4).
Suppose for example user gives the co-ordinate of point 1

i.e. (19^0 15' 00'', 85^0 00' 00'')

Latitude : 19^0 15' 00"

Longitude : 85^0 00' 00"

Then programme displays the following lines

Initialisation parameters (Lambert Conformal Conic Projection)

1.	Semi-major axis of the ellipsoid	:	6377276.300 meters
2.	Eccentricity squared	:	0. 0066378367185
3.	Latitude of first standard parallel	:	019^0 14' 59.9999"
4.	Latitude of second standard parallel	:	019^0 59' 59.9999"
5.	Longitude of origin	:	085^0 29.' 59.9999"
6.	Latitude of origin	:	019^0 14' 59.9999"
7.	False easting	:	0.00000 meters
8.	False northing	:	0.00000 meters

Result of transformation X = -52560, Y = 77

The transformation for other co-ordinates are carried out in the similar manner.

The maps collected from different sources have different geographical locations throughout the area of study. So each map is digitised with respect to their extreme latitudes and longitudes and after that georeferenced with respect to the land use / land cover map. time While georeferencing the dimension of each pixel was kept to 100 meters. For the present study the following maps were digitised. .

1. Base map
2. Bottom temp. contour
3. Flora map

5. Soil map around Chilika
6. Land use / Land cover
7. Vegetation map
8. Temporal change of water spread area
9. River gauge and tide gauge stations around Chilika lake
10. Settlement map of Chilika periphery

The manual digitisation is very a much time consuming work. Land use / land cover map is the largest of all maps digitised and has around 6000 segments. After digitisation the following maps are polygonized.

1. Base map
2. Flora map
3. Soil map around Chilika
4. Land use / Land cover
5. Vegetation map
6. Temporal change of water spread area
7. Settlement map of Chilika periphery

Polygonization is the most time consuming part of this package. For polygonization, the programme first checks the segments, then dead ends. After elimination of errors it creates polygons. At this moment if an error detected then the programme again checks segments

and dead ends after elimination of this error from beginning of those segment which are correct for further proceedings. Amazingly the Land use / Land cover map took more than 500 hours for digitisation and polygonization. For polygonization the following process followed.

*Vector

*Digitise

*Polygon mode

*Check / Make / Update

*Make/Update Polygons

The point information was also digitised in point mode of the *digitise module* and stored in (.pnt) files. Georeferencing is an important operation in every GIS package. It should be perform with adequate number of control points well distributed through out the study area. The typical process is as follows.

*Raster

*Spatial modelling

*Georeference

*Geometric transformation Enter the slave map name: (?) (the name of the map to be georeferenced should be entered here)

*Entering tie point method

*Metric co-ordinates

*Pixel size in meter: 100

- Enter lower X co-ordinate : - 36387
- Enter higher X co-ordinate : 51270

- Enter lower Y co-ordinate : - 4090

- Enter higher Y co-ordinate : 83635

* Transformation function : Affine

Extreme X and Y co-ordinates from the land use / land cover map have been taken for georeferencing all the maps. Satellite data procured from NRSA was in skewed form as shown in Fig 5.2

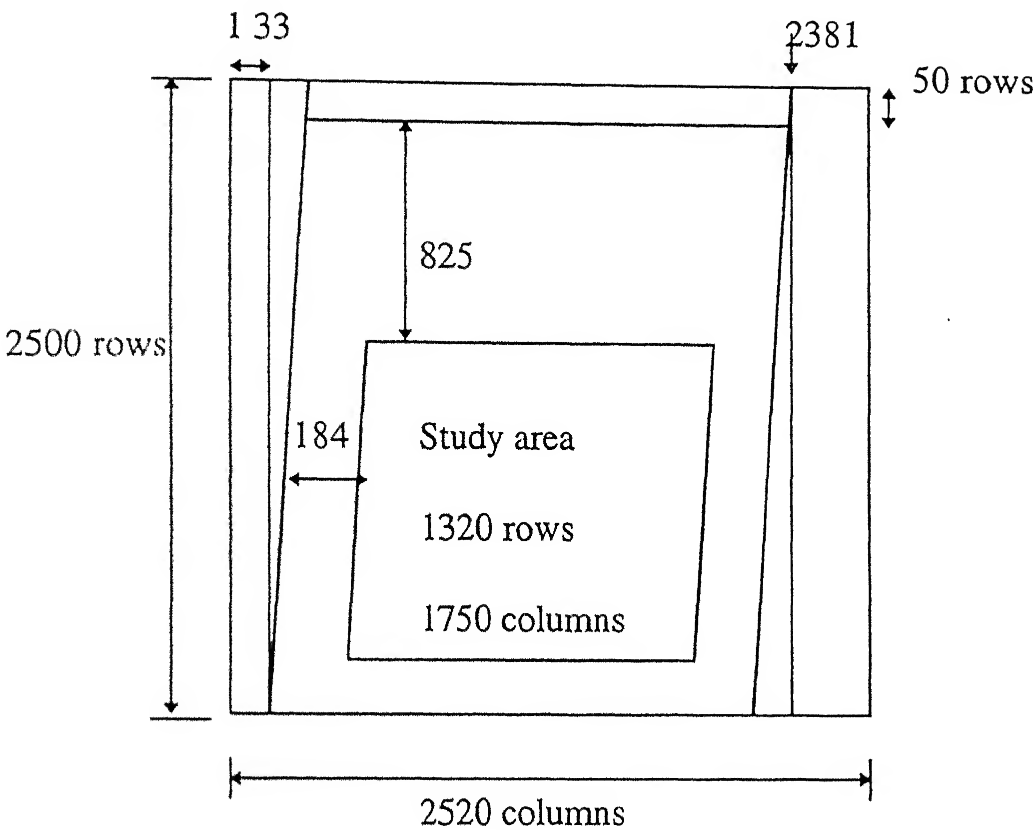

Figure 5.2 Study area extracted from the raw data

After extraction of study area, the four band images were registered with respect to the digitised land use / land cover map. The sigma value for georeferencing was 0.88. The generation of Digital Terrain Model (DTM) was carried out after rasterization and interpolation of contour information and point information with the aid of *3D view*. The comparison / mathematical relation can be established between a point information file and contour information file only when the both are rasterised to same scale.

The procedure for generation of DTM is as follows

For contour information

* Digitisation of contour

    * Rasterize (segment to raster)

        * Interpolation form isolines

            * Display in 3D

For point information

* Digitisation of points

    * Display and Change

        * To raster (rasterization) is done with reference to land use / land cover

Interpolation from points

For the present study moving average gridding method is used.

* $(1/d^n - 1)$

After interpolation from isolines and points, the spread function does not confine within the lakeperiphery and extends to the extreme points. In order to get the exact lake portion, a mask has been digitised using the *onscreen digitisation* module. The backdrop image plays an important role here. It must be noted that the image used for backdrop image must be georeferenced. Then the mask is polygonised and rasterized. The value inside the polygon was kept as 1 and outside as 0. The interpolated map and mask were multiplied using map calculation option. The digital satellite image contains cloud in some region. The mask has been defined after avoiding this.

For the present study maximum likelihood classifier has been used for carrying out all classifications. First, the sample sets were selected from the FCC (in bands 4,3,1) after hecking the mean, standard deviation of the pixels gathered for a specific group. Then the whole image is classified with respect to these samples. The processes is as follows.

* Raster
  * Image processing
    * classification
      * sample
        * enter screen window to sample in: $
          * enter sample set file name
            * classify (maximum likelihood)

Density slicing technique is used for demarcation of different zones after subtraction of two years data at same scale. This application has been used for detection of temperature change, salinity change, pH change and turbidity.

ANALYSIS. AND RESULTS

6.1 WATER SPREAD AREA

The waterspread area extracted from maps collected from different sources and satellite digital data shows a great variation in different seasons. It shows that water spread area increases upto 1050 sq. km in monsoon due to entering of flood water from different rivers. There is a steep slope of mountains as shown in the Figure 6.1. The eroded sediments flow directly into the lake. Therefore, the depth of water in northern and eastern region is shallow due to deposition of sediments. The temporal change of area and perimeter is shown in table 6.1. The overlaying of maps in fig 6.2. shows that the north-eastern side of lake has been filled with sediments carried out by rainwater from mountainous catchment and consequently reduces the water spread area. The bottom profile of lake shows (fig 6.3) that the depth of water in southern sector is relatively higher with the maximum depth is at Kalijai. It also clearly reflects that the sediments from rivers and catchment are deposited in the north-eastern peripheral region.

Table 6.1 Water spread area and perimeter calculated from different sources from (1914-96)

Year	Source	Area (Sq. km)	Perimeter in km
1914	A.Annadale, Kemp	896.00	423.5000
1972-73	SOI	826.00	339.7900
18.1.1973	L_1 MSS Band 7	875.00	359.1712
9.5. 1981	L_2 MSS Band 7	887.00	470.7879
22.11.1985	L_4 MSS FCC	863.00	500.4514
25.5.1986	L_5 TM FCC	790.00	326.5817
24.10.1993	IRS - 1B FCC	928.00	514.7777
2.2.1993	IRS - 1B FCC	813.00	358.0200
19.5.1995	IRS - 1B	1094.00	522.2140
10.7.96	IRS - 1B, LISS - 1	977.81	499.2122

Table 6.2 Bathymetric observations taken at different stations in July 1996

Station Number	Water Depth(m)	Depth computed (m) (3-water depth)
1	0.75	2.25
2	1.18	1.82
3	1.205	1.795
4	1.57	1.43
5	0.775	2.225
6	1.335	1.665
7	1.445	1.555
8	1.485	1.515
9	1.7	1.3
10	1.25	1.75
11	2.05	0.95
12	1.95	1.05
13	2.2	0.8
14	2.25	0.75
15	2.05	0.95
16	2.705	0.295
17	2.85	0.15
18	2.825	0.175
19	1.5	1.5
20	2.3	0.7

Table 6.3 Water quality parameters as recorded in July 1996 at different stations

Station. Number	Transparency in cm.	Temp in ^{0}C	Salinity in ppt	pH
1	26.5	29	2	8.6
2	17.5	28.75	1.37	8.65
3	34.00	29	3.315	8.7
4	26.5	28.25	10.32	8.75
5	43	29.25	3.765	8.65
6	55	29	13.44	8.3
7	82.5	29	18.19	8.5
8	79	28.5	17.84	8.3
9	68	28.25	18.08	8.8
10	49	29.25	20.835	8.85
11	68	28.75	18.215	8.65
12	72	29.25	17.80	8.7
13	90.5	29.25	16.70	8.7
14	82.5	29.25	16.00	8.7
15	87	29.25	15.30	8.75
16	88.5	29	16.00	8.75
17	95	29	15.80	8.7
18	81	29	15.76	8.7
19	122	30	13.69	8.9
20	108	30	12.90	8.5

Table 6.4 Water quality parameters observed in July 1993 at different stations

Station Number	pH Value	Salinity (ppt)
1	8.30	12.50
2	8.35	12.00
3	8.60	3.25
4	8.65	10.33
5	8.65	4.15
6	8.40	14.55
7	8.40	20.85
8	8.40	18.35
9	8.75	18.95
10	8.85	22.9
11	8.75	18.98
12	8.75	18.20
13	8.90	18.35
14	8.90	17.00
15	8.75	15.40
16	8.90	16.25
17	8.85	16.00
18	8.90	16.05
19	8.70	12.79
20	8.70	14.1

6.2 SALINITY

Spatial and temporal variation of salinity was observed in different monitoring stations in different seasons. It is observed that salinity concentration in the lagoon is higher in pre-monsoon than other seasons. Further it has been recorded that the change in salinity from July 1993- July 1996 was maximum in northern sector than other two sectors. The change in salinity is highlighted by density slicing. The decline in salinity in northern region is mainly due to incoming flood water into the lake. The decrease in salinity is due to obstruction of connecting channel between lake and sea. The salinity concentration in different stations in July 93 and July 96 is shown in table 6.4 and 6.3 respectively. After digitisation, rasterization, interpolation, subtraction and density slicing, three zones of salinity change are demarcated and are shown in Figure 6.4. Salinity plays a important role

in determination of biotic factors in the Chilika lagoon. Distribution and seasonality of flora and fauna depends upon the salinity. Research workers like Devasundaram and Roy (1954), Pattnaik (1973, 1978) and Pattnaik and Sarkar (1976) established the interrelationship between salinity and plankton and aquatic plants. Annandale and Kemp (1915) reported that the salinity exercises a continual selective influence on animals of the lake. Most part of the lake except southern part are influenced by fresh water. Depending upon the salinity some selective aquatic microphytes grow luxuriantly in the lake. It has been like observed by certain organisations like Chilika Development Authority, that due to decrease in salinity prawn culture has severely affected.

Table 6.5 Range of change of salinity from 1993 to 96

Status of change	Change in ppt
High	1.2 - 2.5
Moderate	0.75 - 1.2
Low	0 - 0.75

6.3 TRANSPARENCY

The sunlight penetration into the water column of different stations was assessed by Sechi Disc measurement. Transparency of different stations in July 1996 are given in the table 6.3. It is noted that water in southern Chilika is more transparent than rest of the area. The northern zone is entirely turbid because of concentration of sediments. The Rambha zone is more transparent than the other parts of the lake because of its semienclosed condition and less overland flow. During monsoon, the transparency of Chilika water reduces considerably because of inflow of silt laden water. Barkudi-Bhusandhapur is turbid throughout the year because of constant flow of silt loaded water through Daya and Bhargavhi river. Four different zones are displayed in Figure 6.5 after density slicing. The zones created on the basis of some range in transparency difference shown in table 6.6

Table 6.6 Range of transparency concentration observed in July 96

Status	Transparencies range in cm
High turbid	26.0 - 44
Turbid	44 - 80
Low turbid	80 - 90
Still Water	90 - 125

6.4 pH

There is a considerable variation of pH values (range 6.8-9.5) throughout the lake. In this study, change in pH has been detected from 1993 to 96. The change in pH is mainly due to use of food and chemicals used for prawn culture and use of chemicals in agriculture. The pH value is more in southern part of the central region and maximum at Rambha. The four ranges of change in pH is shown in table 6.7. and visual discrimination is seen in Figure 6.6.

Fig. 6.7 Range of change of pH from 1993 to 96

Status	Range
High	0.5-0.65
Moderate	0.35-0.5
Low	0.15-0.35
Very low	0.0-0.15

6.5 TEMPERATURE

Although the variation in temperature is very less, it is classified into four categories as shown in Table 6.7. The change is mainly due to developing industrial area in the southern part of lake periphery. Waste water of the industries, oils from bilge water of naval cadet training ships and power driven boats are being discharge into the lake. The range of change is shown in Table 6.8.

Table 6.8 Range of change of temperature from 1987 to 96

Status of change	Range (°C)
High	0.5-1.0
Moderate	0.35-0.5
Low	0.0-0.3
NO	0.0

6.6 WEED COVERAGE

Total area of weeds which include emergent, submergent and floating type, has been increasing rapidly since decades. The present study along with previous observations clearly concludes that the weed growth is very rapid and unchecked. From the present study it reveals that rate of weed growth is 18.88 km^2 per year. The depth of water, salinity and nature of substratum are to a large extent, responsible for the distribution and abundance of aquatic plant communities in the lake water. The aquatic vegetation like Potamogation pectinatus, Najas faveolate are widely distributed and of quantitative importance. Potamogation pectinatus, being the most dominant element, grows well at any depth of water and withstand wide range of salt concentration. Table 6.9 and 6.10 shows Area covered by different weeds collected from ground truth data of year 1987 after registration and Area covered by different weeds as classified from satellite data of 1996. Figure 6.8 and 6.9 shows the image photographed from the screen for the above mentioned items respectively.

Table 6.9 Area covered by different weeds collected from ground truth data of year 1987 after registration.

Name	Area covered in km^2
Clear Water	461.28
Islands	81.65
Najas	16.44
Najas & Algae	6.77
Potamogation, Algae	35.02
Potamogation, Fresh Water Vegetation	21.51
Potamogation, Najas	46.74
Potamogation	161.42
Scirpus, Fresh Water Vegetation, Grass	65.64
Scirpus	14.54
Scirpus, Fresh Water Vegetation	27.63

Table 6.10 Area covered by different weeds as classified from satellite data of 1996

Name	Area covered in km^2
Algae	40.67
Potamogation & Najas	129.89
Freshwater vegetation	113.94
Potamogation & Algae	269.39
Scirpus	114.54
Grass	2.04
Clear water	291.10

6.7 LANDUSE / LAND COVER

The table 6.11 and 6.12. shows the land use / land cover historical and current classified satellite land cover status respectively. It is observed that the area covered by the dense forest was 92.989 km^2 in 1987 and 69.71 km^2 in 1996. It has decreased by 2.586 km^2 per year. The area of waste land also increased due to improper reclaimation. The snapped photo for both are shown in Figure 6.10 and 6.11 respectively. The detail comparison is not done.

Table 6.11 Area covered by different components of land use / land cover map from ground truth data of year 1987 after polygonisation and rasterisation

Category	Area in km^2
Dense forest	92.989
Degraded forest	69.769
Sparse forest	19.27
Degraded plantation	18.31
Wet mud	46.19
Agricultural land	697.099
Acquiculture	15.545
Barren rocks	85.449
Beach ridge	32.61
Beach sand	26.35
Built of lands	18.57
Chilika lake	875.55
Dry mud	20.28
Grassy land	20.24
Grassy mud	62.609
Ponds & Reservoir	7.77
Reclaimed land cultivation	95.949
River	31.85
Sand with scrubs	13.63
Sandy islands	11.85
Swamp	49.01
Under water	1.76
Undulating uplands	32.75

Table 6.12 Area covered by different land cover parameters as classified from satellite data of 1996

Name	Area in km^2
Swamp	157.01
Agricultural land	1112.24
Dense forest	69.71
Sparse forest	145.24
Wet lands	165.29
Grassy lands	743.65
Waste lands	212.07

The vegetation classification has been done on satellite data and area covered by each is calculated. Here dense vegetation includes dense, sparse forests, sparse include agricultural lands and degraded include scrubs. From this observation it indicates that

the area excluding chilika lake and vegetation cover is around 738.6 km2 which include barren lands, hills and wastelands. The management of this area should be done carefully.

Table 6.1: Vegetation category extracted from the classification of satellite image

Name	Area in km^2
Dense vegetation	881.77
Sparse vegetation	452.41
Degraded vegetation	250.03

CHAPTER 7

CONCLUSIONS AND RECOMMENDATION

It is observed that the Chilika environment has been seriously affected due to many factors like rapid growth of weeds, heavy siltation, depletion in salinity level and deforestation. The following conclusions are derived from the analysis of the present study.

(1) Growth of weed inside the lake is very rapid, approximately 18.908 km^2 per year. The northern zone is full of weeds due to low salinity where as some portion in southern region is covered with clear water due to high saline water. So it is obvious that the weed growth also depends upon salinity concentration to a considerable extent.

(2) Deforestation of dense forest is at the rate of approximately 2.586 km^2 per year.

(3) Change of salinity is high in northern sector than that of other portion of the lake.

(4) The variation of pH is more near Balugaon and Rambha

(5) Barren hills and pediments in the western side of Chilika contribute a lot of sediment due to erosion and overland flow/stream flow.

Some eminent researchers have already carried out the intensive study on the changing nature of this lake and recommended different measures to be taken by the corresponding authority to preserve this nice natural environment. A few of them briefly explained below.

1. Now the northern part is covered with different type of weeds. These weeds also arrest sediments which are brought to Chilika through streams rivers and overland flow. Massive use of fertilisers in the shoreline paddy field, enter into the lake during heavy flood and induce the luxurient growth of macrophytes in the lagoon. As the sediments

are rich in nutrients, they augment the growth of weeds. This process is repeated in a cyclic manner which result in a rapid growth of weeds. Free flushing water and increase in the salinity level in the lake water may cause decrease in weed growth.

2. The ecosystem of the lagoon is presently under a great stress due to flood discharge and inadequate tidal influx. The estimated 375000 million cusec fresh water flow brings in 3.65 lakh tonnes of silt annually, large part of which is deposited in the northern fringe areas of the lake (ORSAC, 95). The out flow is slow due to constricted channel of a length of 35 kms. Rate of shrinkage of water spread area is approximately 1.5 km^2 per year and the north eastern side of the lake is heavily sedemented.The siltation around the islands and channel zones is remarkable. The satellite imagery clearly depicts the emergent lands which hence been mapped for healthy maintainance of the lake. The water spread area should be restricted to at least 900 km^2.
3. It has also been observed that salinity level in lagoon water is gradually depleted. Due measures must be taken to increase it upto 15 ppt for the better growth of prawn in the lagoon.
4. Necessary management practices i.e. plantation etc. may be adopted to prevent erosoion of arid mountaneous region.
5. The entire lake has been divided into 3 zones after proper processing of remotely sensed data based on physio-chemical and biotic characteristics. Hydrological, meteorological, limnological and biological studies need to be continued for keeping a close watch on the ecosystem.

6. The silt flow of Daya, Bhargavi and other rivers have not been gauged systematically. However it is necessary to take measures to arrest silt and allow controlled discharge into the lake.

7. The agricultural land around the lake can be taken up for intensive development with proper planning. Ground water utilisation in addition to limited flow irrigation, can be planned. It is essential that the lake should be surrounded by green belt. The lake side slope should be covered by grasses. Access to the lake is to be extremely limited and at all such access points and on shore belt of areas adequate measures for controlling the drainage and affluent should be taken. The natural drainage has to be fully drained with silt traps and the last reaches would be developed as grass water ways.

8. Environmental monitoring at regular intervals i.e. pre-monsoon, monsoon, post-monsoon and pre-summer, may be taken to study the exact changes in the environmental parameters and prepare a data base for lake management.

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APPENDIX 1

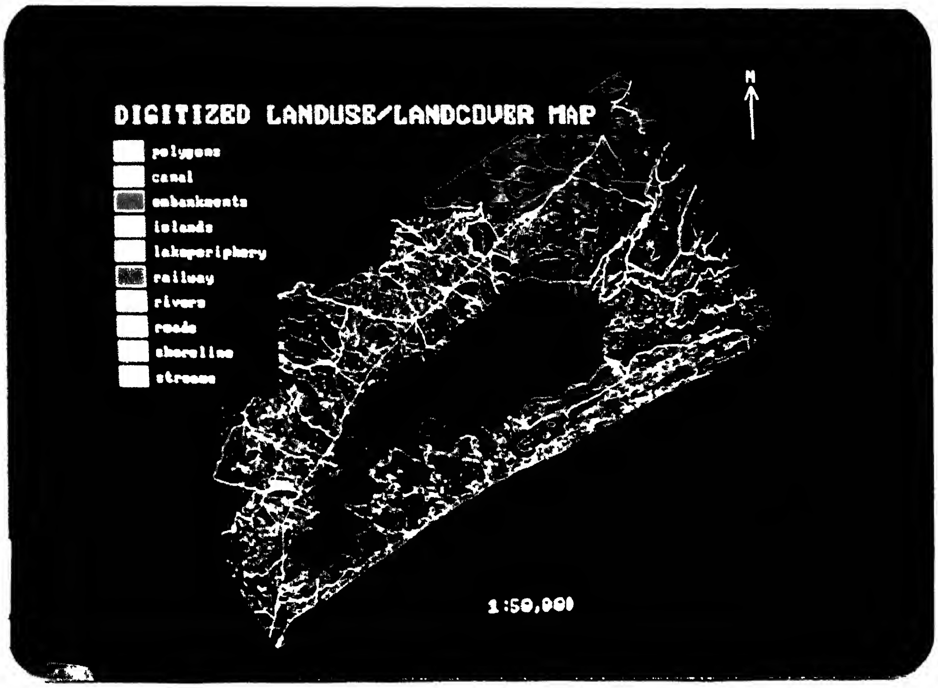

Fig. 4.1Digitized land use / land cover map

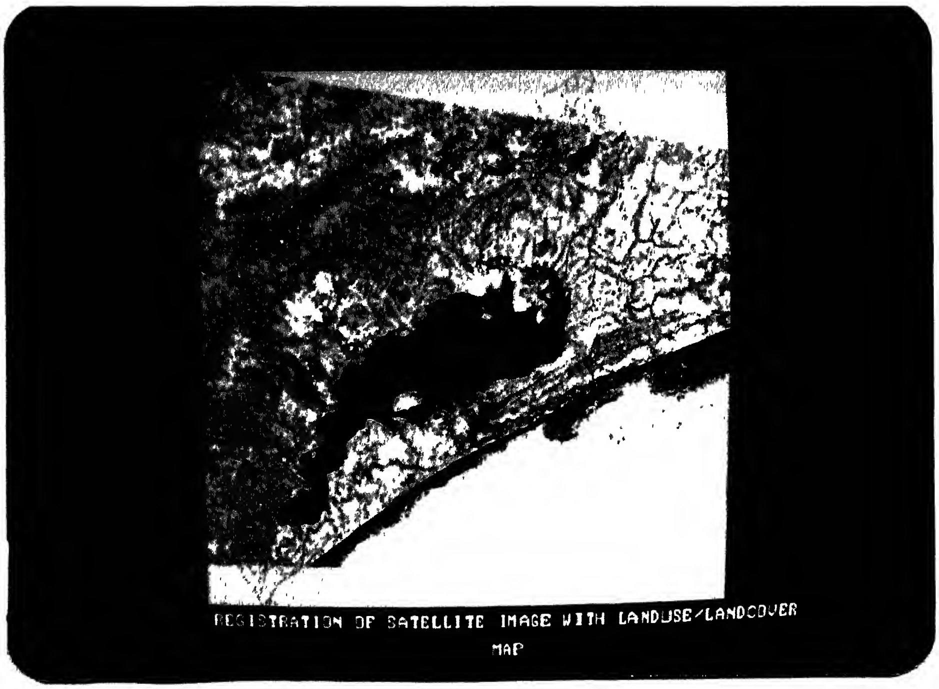

Fig. 4.2 Satellite data after registration with land use / land cover map

Fig. 5.3 FCC using band 4,3,2

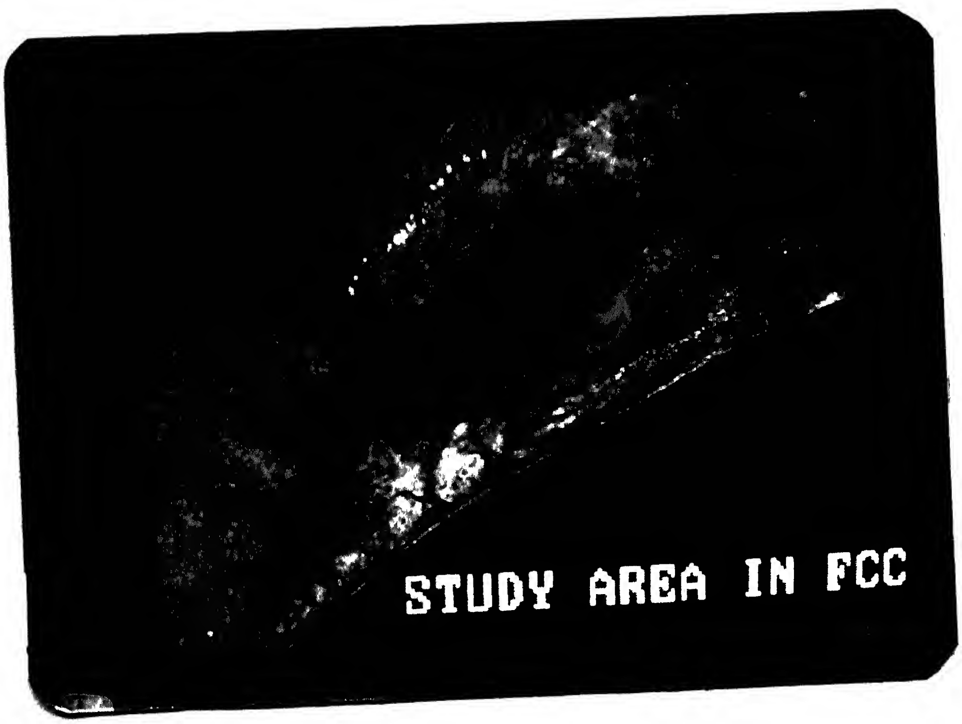

Fig. 5.4 Study area in FCC

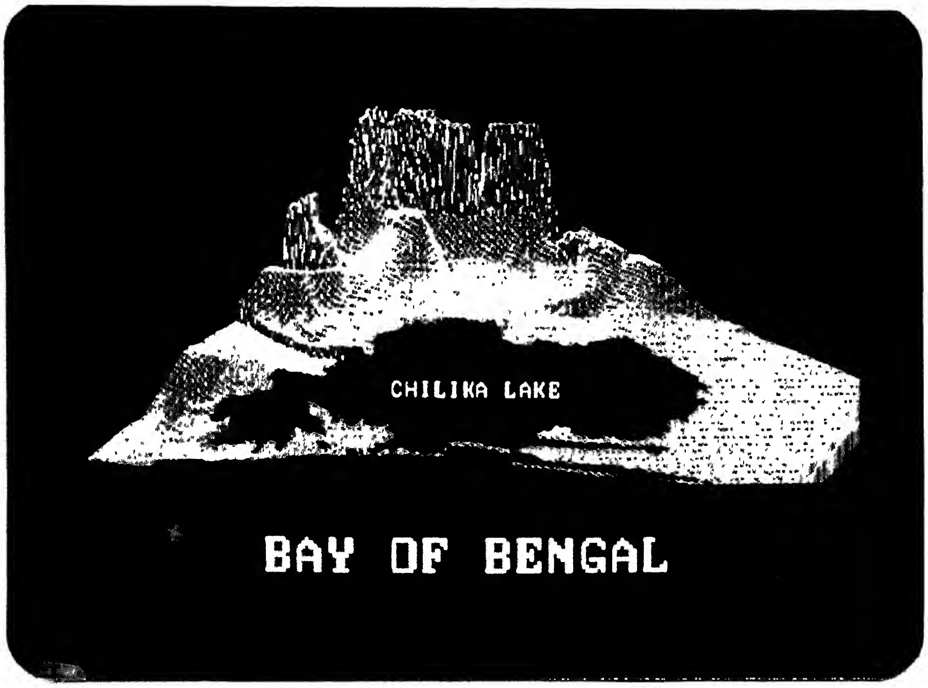

Fig. 6.1 DTM of the lake region

Fig. 6.2 Overlaying of digitized water spread map after registration

Fig. 6.3 Bottom surface profile of the lake

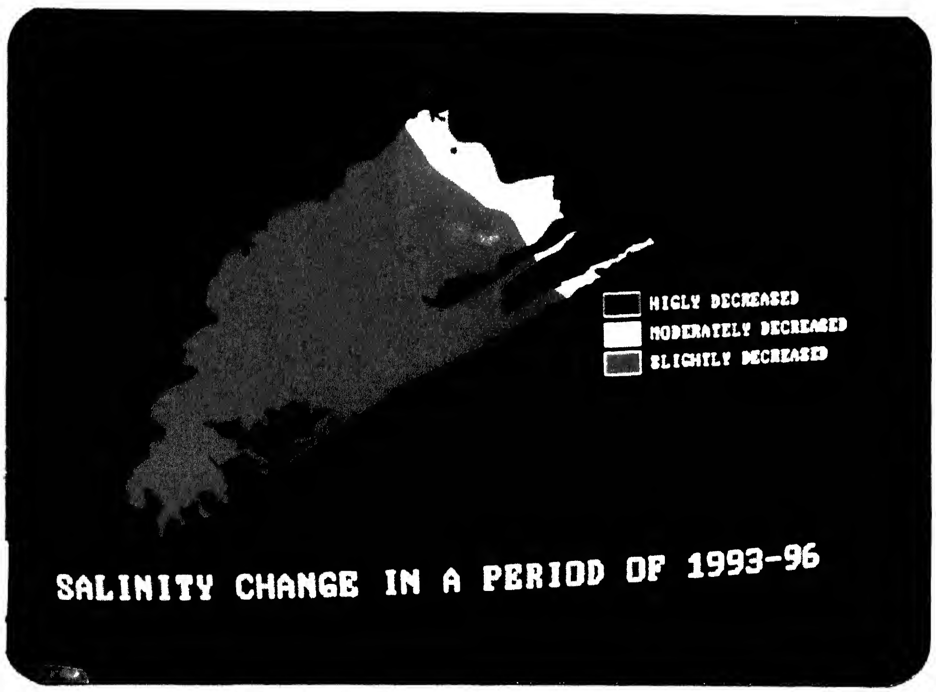

Fig. 6.4 Rate of change of salinity from 1993 to 1996

Fif. 6.5 Transparency map

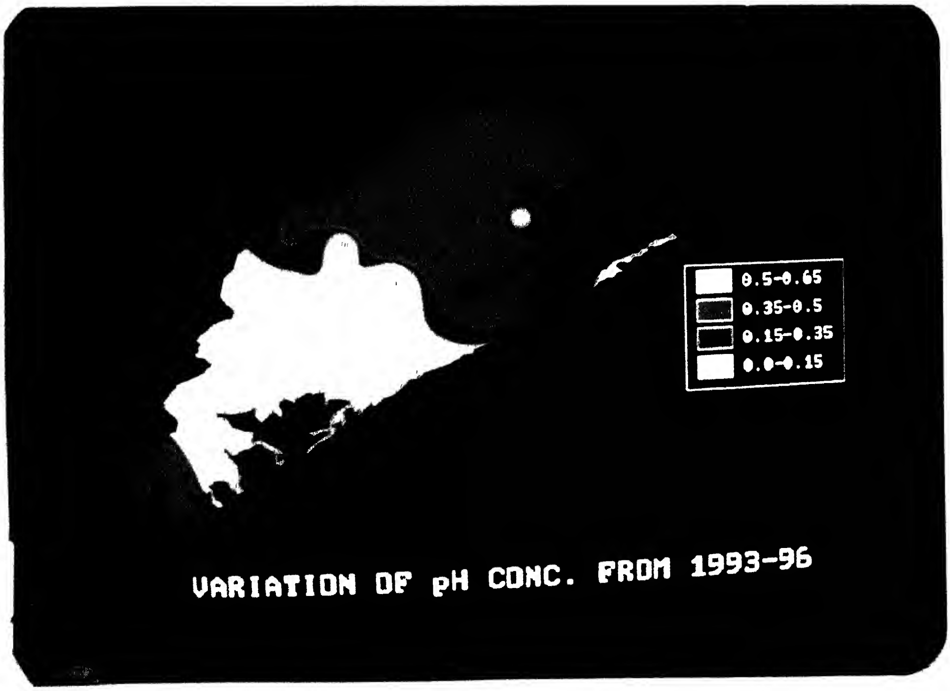

Fig. 6.6 Rate of change of pH from 1993 to 1996

Fig. 6.7 Rate of change of temperature from 1987 to 1996

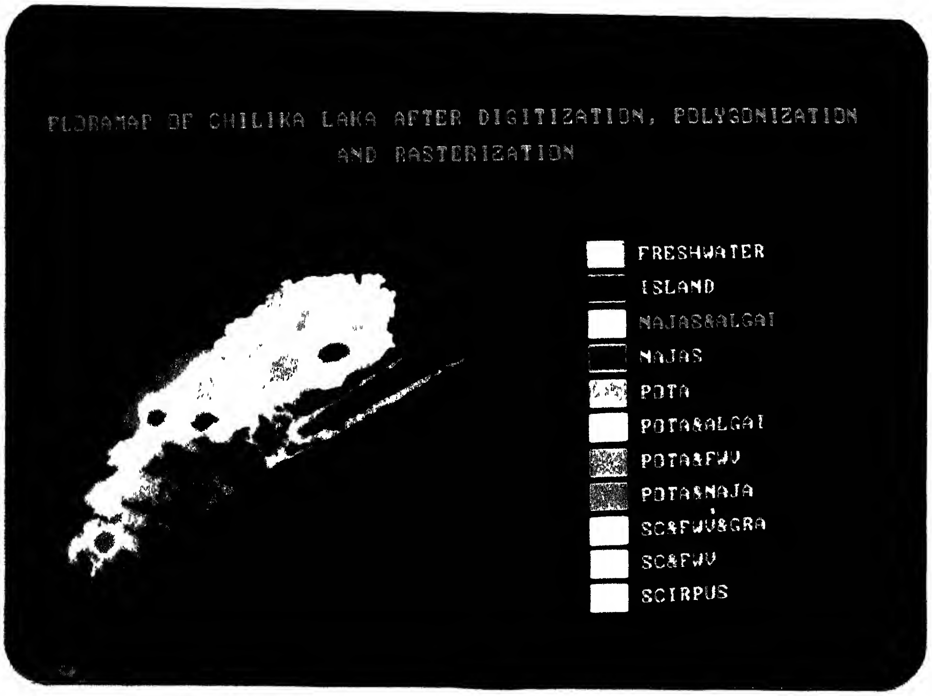

Fig. 6.8 Flora map of Chilika lake obtained from 1987 data

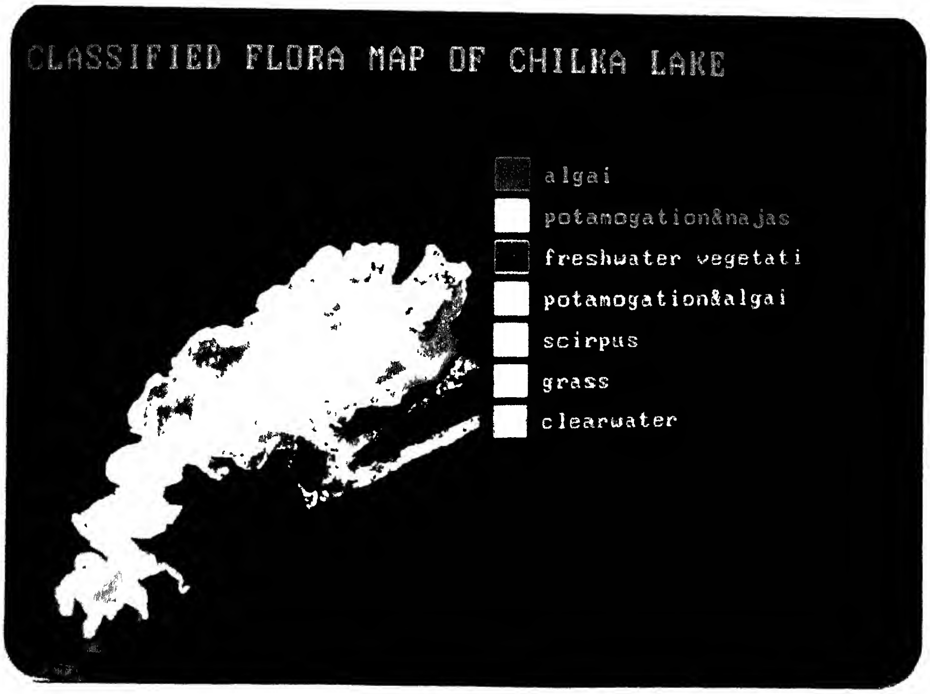

Fig 6.9. Flora map of Chilika lake classified from 1996 satellite data

Fig. 6.10 Land use / land cover map of 1987

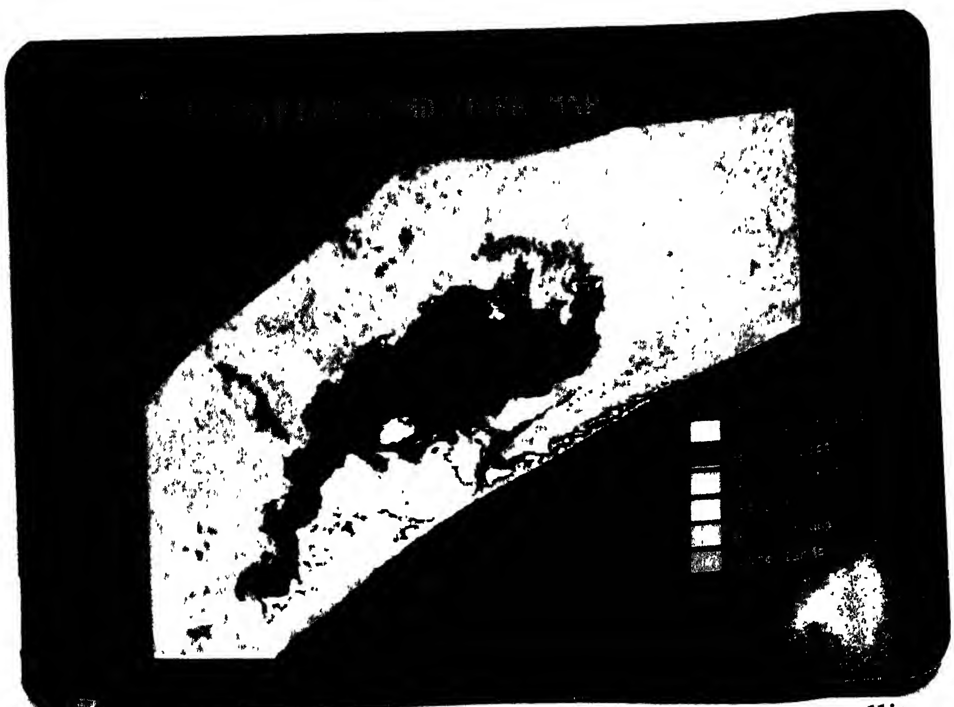

Fig 6.11. Land cover map derived from classification of satellite (

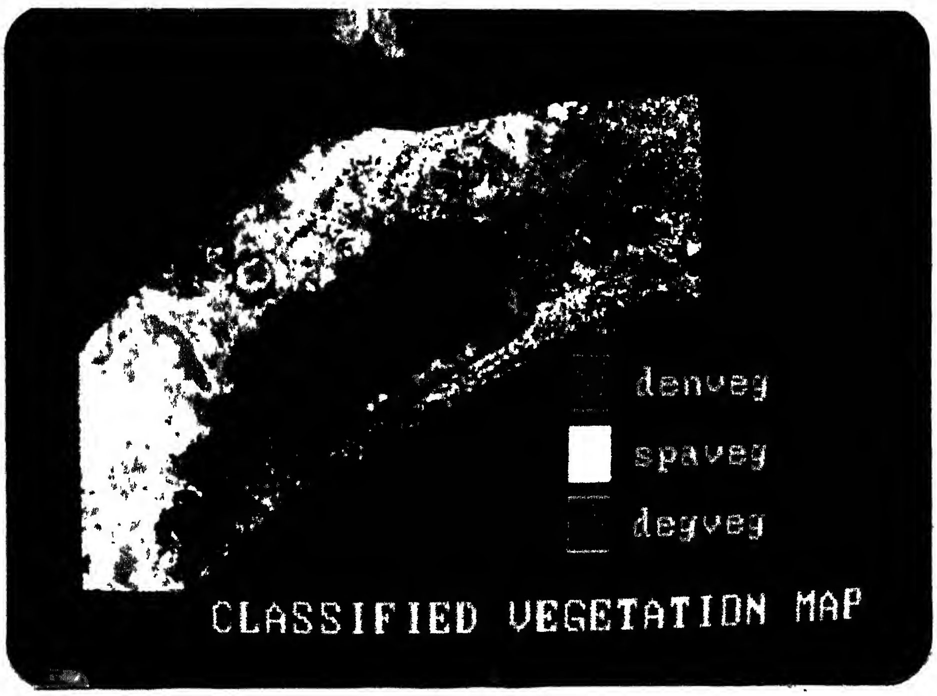

Fig. 6.12. Classified vegetation map from 1996 image